DISCRETE CHOICE MODELING OF ENVIRONMENTAL SECURITY

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EXECUTIVE SUMMARY
DISCRETE CHOICE MODELING OF ENVIRONMENTAL SECURITY

The presence of overpopulation or unsustainable population growth may place pressure on the food and water supplies of countries in sensitive areas of the world. Severe air or water pollution may place additional pressure on these resources. These pressures my generate both internal and international conflict in these areas as nations struggle to provide for their citizens. Such conflicts may result in United States intervention, either unilaterally, or through the United Nations. Therefore, it is in the interests of the United States to identify potential areas of conflict in order to properly train and allocate forces. The purpose of this research is to forecast the probability of conflict in a nation as a function of its environmental conditions.

Probit, logit and ordered probit models are employed to forecast the probability of conflict and the probability of a given level of conflict. Data from 95 countries is used to estimate the models. Probability forecasts are generated for these 95 nations. Out-of sample forecasts are generated for an additional 22 nations. These probabilities are then used to rank nations from highest probability of conflict to lowest. The results indicate that the dependence of a nation's economy on agriculture, the rate of deforestation, and population density are important variables in forecasting the probability and level of conflict.

These results indicate that environmental variables do play a role in generating or exacerbating conflict. It is unclear that the United States military has any direct role in mitigating the environmental conditions that may generate conflict. A more important role for the military is to aid in data gathering to generate better forecasts so that troops are adequately prepared when conflict arises.

ABSTRACT

The presence of overpopulation or unsustainable population growth may place pressure on the food and water supplies of countries in sensitive areas of the world. Severe air or water pollution may place additional pressure on these resources. These pressures my generate both internal and international conflict in these areas as nations struggle to provide for their citizens. Such conflicts may result in United States intervention, either unilaterally, or through the United Nations. Therefore, it is in the interests of the United States to identify potential areas of conflict in order to properly train and allocate forces. The purpose of this research is to forecast the probability of conflict in a nation as a function of its environmental conditions.

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I. INTRODUCTION

The presence of overpopulation or unsustainable population growth may place pressure on the food and water supplies of countries in sensitive areas of the world such as the Middle East, Africa, South and Southeast Asia, Eastern Europe, and the former Soviet Republics. Severe air or water pollution may place additional pressure on these resources. These pressures my generate both internal and international conflict in these areas as nations struggle to provide for their citizens. Such conflicts may result in United States intervention, either unilaterally, or through the United Nations. Therefore, it is in the interests of the United States to identify potential areas of conflict in order to properly train and allocate forces. The purpose of this research is to forecast the probability of conflict in a nation as a function of its environmental conditions.

Three limited-dependent variable models, probit, logit and ordered probit, are employed to forecast the probability of conflict (probit and logit models) and the probability of a given level of conflict (LOW, MODERATE, HIGH, or VERY HIGH – in the ordered probit models). Data from 95 countries is used to estimate the models. Probability forecasts are generated for these 95 nations as well as out-of sample forecasts for an additional 22 nations. These probabilities are then used to rank nations from highest probability of conflict to lowest. The following countries consistently fall in the top ten countries with the highest probability of conflict, regardless of the modeling technique employed: Angola, Ethiopia, Myanmar, Uganda, Ghana, Cambodia, Laos, and Somalia. These results are not surprising. The results indicate that the dependence of a nation's economy on agriculture, the rate of deforestation, and population density are important variables in forecasting the probability and level of conflict.

It is clear that environmental variables do play a role in generating or exacerbating conflict. It is unclear that the United States military has any direct role in mitigating the environmental conditions that may generate conflict. A more important role for the military is to aid in data gathering to generate better forecasts so that troops are adequately prepared when conflict arises.

II. BACKGROUND

Recent research in political science and international relations has established links between environmental scarcity and intra- and international conflicts[1]. Most of this research has focused on the analysis of case studies and use of correlational techniques such as the Pearson's Chi-Squared Test to identify the relationships between environmental variables and development of conflict[2]. Because the route between environmental stress and conflict is usually circuitous and indirect[3], this research is important in developing an understanding of how environmental scarcity leads to conflict. However, because the data in case studies necessarily occurred in the past, it is difficult to use such data to forecast the current potential for conflict, as environmental or political conditions, or both, may have changed.

Maxwell and Reuveny (1998) draw on the case-study research to develop a theoretical model that relates resource dynamics, population dynamics, and conflict. The model is a modification of Brander and Taylor's (1998) dynamic predator-prey model of population growth and renewable resource use. This model provides an explanation for population crashes such as that of the society on Easter Island. Maxwell and Reuveny establish a steady state equilibrium between the population and resource use. They then demonstrate that an exogenous shock to the system may force it into a "conflict zone" (p.

12). This conflict zone is characterized by low levels of per capita resources. They show that it is possible for the country to cycle between conflict and peace as it returns to the steady state following the shock.

This dynamic model establishes the basis for the determination of the independent variables that will be used to predict conflict. The variables are intended to be indicators of the degree of pressure that a nation's population is placing on its resources and may indicate a nation's vulnerability to a shock that may push it into Maxwell and Reuveny's so-called conflict zone. The following section describes the econometric models used to predict conflict. Section IV contains a description of the data and sources. Section V presents the results followed by some policy recommendations and conclusions in Section VI.

III.   LIMITED-DEPENDENT VARIABLE ECONOMETRIC MODELS

The level of threat or the potential for conflict that a nation poses is a latent, or unobserved variable in that it is not directly measurable on a continuous scale. It is possible, however, to construct indicator variables to represent the underlying latent threat variable. The construction of such variables is the principle behind limited-dependent variable models in econometrics. In the simplest case, the indicator variable is a binary variable of the form: 0 if a country is not a threat, 1 if a country is a threat. If we allow y^* to represent the latent variable measuring actual threat, and y to be the binary indicator variable, then values are assigned to y as follows:

$$y = 0 \text{ if } y^* \leq 0 \qquad\qquad (1)$$
$$y = 1 \text{ otherwise}$$

where the true underlying model for y^* is:

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$$\mathbf{y^*} = \beta'\mathbf{X} + \varepsilon \qquad\qquad (2)$$

y^* is an n x 1 vector of the threat that a country poses, X is an n x k matrix of explanatory

variables, in this case variables reflecting the level of environmental stress in a nation, β is

a k x 1 vector of parameters that indicate the effect of the explanatory variables on the

level of conflict, and ε is an n x 1 vector of error terms reflecting individual deviations

from mean behavior in the population. If it were possible to observe y^*, one could simply

run a standard linear regression using ordinary least squares (OLS) to determine the values

of the coefficients. However, because the observed indicator variable is discrete, OLS is

not applicable. Two models are common. If ε is assumed to have a standard normal

distribution, then a probit model is estimated. If ε is assumed to have an extreme value

distribution, then a logit model is appropriate. In either case, a likelihood function is

specified that describes the probability of y given the values of the explanatory variables.

Maximum likelihood estimation is then used to estimate the coefficients.[4]

In many cases the indicator can take on a number of discrete values, indicating the

level of threat or conflict that a nation poses. The underlying model for the latent variable

is the same, but the indicator variable takes the form:

$$
\begin{aligned}
&y = 0 \text{ if } y^* \le 0 \\
&y = 1 \text{ if } 0 < y^* \le \mu_1 \\
&y = 2 \text{ if } \mu_1 < y^* \le \mu_2 \qquad\qquad (3)\\
&\vdots \\
&y = J \text{ if } \mu_{J-1} \le y^*
\end{aligned}
$$

If the assumption is that the error terms have a standard normal distribution, which is

typically the case, then the model is an ordered probit model. As in the binary probit

model, the likelihood function is specified and the parameters are computed using maximum likelihood estimation.

Three models are estimated for this research. In the first two, probit and logit, the dependent variable is either 0, no threat of conflict, or 1 a threat of conflict. In the third model, the dependent variable is a discrete variable ranging from 0 to 3, where 0 represents low threat of conflict and 3 represents a very high threat of conflict. The following section describes the data used for both the dependent and independent variables in the model.

IV. DATA

The dependent variable data is the Coplin-O'Leary 18-month and 5 year risk of turmoil in a country, from Political Risk Services (PRS), a provider of international data to businesses and research institutions. The term turmoil refers to, "...large-scale protests, general strikes, demonstrations, riots, terrorism, guerrilla warfare, civil war, and cross-border war. It also includes turmoil caused by a government's reaction to unrest."[5] Political Risk Services rates the risk of turmoil as either LOW, MODERATE, HIGH, or VERY HIGH. These ratings are useful because it is straightforward to translate them into binary and discrete variables for the logit, probit, and ordered probit models. In addition, the criteria that PRS uses to classify a country according to turmoil risk are comparable to the stages of conflict posited by Jongman (1994). Table 1 reports a comparison of the PRS and Jongman classifications of conflict.

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Table 1. Comparison of Conflict Definitions

PRS Category	Jongman Classification
LOW • Most discontent is expressed peacefully • Violence from political causes is extremely rare	Stable Social System • High degrees of political stability and regime legitimacy
MODERATE • May be affected by occasional riots, acts of terrorism, and significant levels of labor unrest or other kinds of discontent	Political Tension Situation • Growing levels of systemic frustration and increasing social and political cleavages along sectarian identities
HIGH • Levels of violence or potential violence that could seriously affect international business	Serious Dispute Stage • Erosion of political legitimacy of the national government and rising acceptance of sectarian politics
VERY HIGH • The level of turmoil approaches a state of war	Lower Intensity Conflict • Open hostility and armed conflict among factional groups; regime repression and insurgency
(Source: http://www.countrydata.com/polriskrating.html)	High Intensity Conflict • Open warfare among rival groups (Source: Jongman (1994), Appendix 1)

The PRS data is transformed into binary and discrete dependent variables. For the binary dependent variable, a country receives a score of 0 (no risk) if either the 18-month or 5-year PRS turmoil risk rating is LOW. Otherwise, the country receives a score of 1. This dependent variable is employed in the estimation of the logit and probit models. The discrete dependent variable corresponds to the PRS turmoil risk levels as follows: 0 = LOW, 1 = MODERATE, 2 = HIGH, 3 = VERY HIGH. Because the discrete dependent variable has a finer gradient, it includes more information. This additional information should result in a more accurate forecast.

The dependent variables are chosen to reflect the level of stress on a nation's environment. Homer-Dixon (1994) posits six types of environmental change that are plausible sources of conflict. They are:

1. greenhouse-induced climate change

2. stratospheric ozone depletion

3. degradation and loss of good agricultural land

4. degradation and removal of forests

5. depletion and pollution of fresh water supplies

6. depletion of fisheries[6]

Because the data on the first two sources is more global in nature, it is difficult to measure their effects on a given country. Therefore, independent variables that focus on the final four sources of conflict are included in the model. The variables were obtained from numerous sources, such as the World Resources Institute, the United Nations Population Fund, and the World Food Programme. Data from 95 countries is employed in the estimation of the model. Forecasts are generated for these 95 countries, plus out-of-

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sample forecasts for 22 additional countries. The ready availability of data over the internet made the construction of the data set a straightforward process. Availability of internet data should be a boon to future research in this area. Table 2 reports the definitions of the independent and dependent variable data, as well as their sources. Table 3 lists the countries included in the data set. Table 4 reports descriptive statistics of the variables, and Table 5 reports the correlation matrix of the variables.

V.   REGRESSION RESULTS

Table 6 reports the results of the probit estimation. The coefficients from the probit model are not directly interpretable. Rather, the marginal effects of the independent variables, which are reported in the table, are the key indicators of the effect of the environmental variables on the probability of conflict. These marginal effects are the effect of a change in the independent variable on the probability of conflict, evaluated at the margin. The two significant variables are the percent of Gross Domestic Product from agriculture and the rate of deforestation. Dependence of an economy on agriculture increases the probability of conflict. If an economy is dependent on agriculture, it is more vulnerable to shocks. Such shocks may then push a country into the conflict zone, as in Maxwell and Reuveny (1998). The effect of deforestation on conflict is actually the opposite of what Homer-Dixon (1994) and others have predicted. These results indicate that as deforestation increases, the probability of conflict falls. This counterintuitive result stems from the fact that most countries with high conflict ratings have negative rates of deforestation (negative *de*forestation = net *in*crease in forest area). Perhaps this is indicative of the fact that deforestation is not a major environmental problem. Another possibility is that this measure of deforestation, percent change in total forest area is

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Table 2. Data Definitions and Sources

Variable Name	Definition	Source
THREATB	Binary threat variable 0 if either 18-month or 5-year turmoil risk classification is LOW	Political Risk Services
THREAT18	0 = LOW 1 = MODERATE 2 = HIGH 3 = VERY HIGH 18-month risk of turmoil	Political Risk Services
THREAT5	0 = LOW 1 = MODERATE 2 = HIGH 3 = VERY HIGH 5-year risk of turmoil	Political Risk Services
POPG90_95	Average annual change in population (%), 1990-1995	*World Resources 1996-97,* Table 8.1
POPG00_05	Average annual projected change in population (%), 2000-2005	*World Resources 1996-97,* Table 8.1
POPDENS	Population per 1000 hectares, 1995	*World Resources 1996-97,* Table 9.1
POPARAB	Population per hectare of arable land	United Nations Population Fund, *State of the World Population 1998*
FOODAID	Total food aid deliveries 1997 (1000 tons)	World Food Programme
AGGDP	% of Gross Domestic Product from agriculture, 1993	*World Resources 1996-97,* Table 7.1
DEFOREST	Annual % change in forest and other wooded land 1981-90 (For Europe, Canada and Australia, Annual % change in total forest, 1981-90) Values for USSR used for the Central Asian Republics and Russia Values for Yugoslavia used for Bosnia, Croatia, and Macedonia,	*World Resources 1996-97,* Table 9.2
ENGIMP	Net commercial energy imports as a % of consumption, 1993	*World Resources 1996-97,* Table 12.2
H2OUSE	Annual withdrawals of water as a % of annual internal renewable water resources	*World Resources 1996-97,* Table 13.1
FLOW	Annual river flows from other countries (cubic km)	*World Resources 1996-97,* Table 13.1

Table 3. Countries in Data Set

Countries Used in Estimation				
Africa	Europe	North & Central America	Ecuador	Singapore
Algeria	Austria	Canada	Guyana	Sri Lanka
Botswana	Belgium	Costa Rica	Paraguay	Syria
Cameroon	Bulgaria	Cuba	Peru	Thailand
Congo	Czech Republic	Dominican Republic	Suriname	Turkey
Cote d'Ivoire	Denmark	El Salvador	Uruguay	United Arab Emirates
Egypt	Finland	Guatemala	Venezuela	Vietnam
Gabon	France	Haiti		Yemen
Ghana	Germany	Honduras	Asia	
Guinea	Greece	Jamaica	Bangladesh	Oceania
Kenya	Hungary	Mexico	China	Australia
Libya	Ireland	Nicaragua	India	New Zealand
Morocco	Italy	Panama	Indonesia	Papua New Guinea
Nigeria	Netherlands	Trinidad & Tobago	Iran	
South Africa	Norway		Iraq	
Sudan	Poland		Israel	
Tunisia	Portugal	South America	Japan	
Zaire	Romania	Argentina	Korea, South	
Zambia	Russia	Bolivia	Kuwait	
Zimbabwe	Spain	Brazil	Malaysia	
	Sweden	Chile	Myanmar	
	Switzerland	Colombia	Oman	
	Ukraine		Pakistan	
	United Kingdom		Philippines	
			Saudi Arabia	
Out-of-Sample Forecast Countries				
Africa	Europe	Middle East	Former Soviet Central Asian Republics	Asia
Central African Republic	Bosnia	Afghanistan	Kazakhstan	Cambodia
Eritrea	Croatia	Jordan	Kyrgyzistan	Korea, North
Ethiopia	Macedonia	Lebanon	Tajikistan	Laos
Rwanda	Yugoslavia		Tukmenistan	Nepal
Somalia			Uzbekistan	
Uganda				

Table 4. Descriptive Statistics of Variables

Variable	Mean	Standard Deviation
THREATB	0.5368	0.5013
THREAT18	0.9263	0.9253
THREAT5	0.8526	0.8748
POPG90_95	1.6705	1.4660
POPG00_05	1.4726	1.0718
POPDENS	1504.0632	4869.0685
POPARAB	3.3553	8.2816
ENGIMP	-104.3602	493.2578
FOODAID	31.0232	83.8367
AGGDP	15.9033	12.6748
DEFOREST	-0.5838	1.1752
H2OUSE	27.3025	86.4736
FLOW	118.6035	253.2984

Table 5. Correlation Matrix of Variables

	THREATB	THREAT18	THREAT5	POPG90_95	POPG00_05	POPDENS
THREATB	1.0000					
THREAT18	0.9131	1.0000				
THREAT5	0.8844	0.8999	1.0000			
POPG90_95	0.7334	0.7249	0.6803	1.0000		
POPG00_05	0.7626	0.7662	0.7656	0.8847	1.0000	
POPDENS	0.1300	0.1188	0.1204	0.1681	0.1604	1.0000
POPARAB	0.3035	0.3268	0.3170	0.4179	0.4639	0.1592
ENGIMP	-0.2470	-0.2422	-0.2538	-0.2711	-0.3631	0.0463
FOODAID	0.4121	0.3703	0.3412	0.3643	0.3903	0.2109
AGGDP	0.7680	0.7416	0.7424	0.7682	0.8030	0.1653
DEFOREST	-0.5043	-0.5361	-0.3906	-0.4457	-0.5022	-0.1155
H2OUSE	0.2329	0.1602	0.2508	0.3223	0.3493	0.0767
FLOW	0.4292	0.3652	0.4458	0.3439	0.3589	0.1058

	POPARAB	ENGIMP	FOODAID	AGGDP	DEFOREST	H2OUSE	FLOW
POPARAB	1.0000						
ENGIMP	-0.1814	1.0000					
FOODAID	0.1960	-0.1642	1.0000				
AGGDP	0.3417	-0.1448	0.5026	1.0000			
DEFOREST	-0.2385	0.0481	-0.2675	-0.4171	1.0000		
H2OUSE	0.0890	-0.1332	0.0535	0.2233	0.1608	1.0000	
FLOW	0.1223	-0.0889	0.4320	0.3715	-0.2537	0.0296	1.0000

flawed. Perhaps this measure reflects older, larger trees being replaced with smaller, younger trees. A measure such as change in total board feet of forest, or change in a specific type of forest, such as old growth or hardwood, may be more appropriate. However, data on these variables is currently sparse at best. The likelihood ratio statistic, lambda, for the test that the model has no explanatory power is 42.96. This value is significant at levels well below 1%.

Table 7 reports the logit results. These results closely mirror the probit model results. This result is not uncommon. For well-behaved data, the logit and probit models generate very similar results. There is no compelling reason to choose one model over the other. As in the probit results, the marginal effects of the independent variable on the probability of conflict are reported. One should note, however, that they are just a constant multiple (in this case 0.25) of the logit coefficients. This is a feature of the logit model. The marginal effects in the two models are identical in sign for all variables and similar in magnitude. As in the probit model, percentage of GDP from agriculture and the rate of deforestation are the significant variables. The likelihood ratio statistic for the test that the model has no explanatory power is 42.7, which is significant at any standard level.

Tables 8 and 9 report the results for the 18-month and 5 year ordered probit models, respectively. In these models, the significant variables have changed. The rate of deforestation still has a negative effect on conflict in the 18-month model, but it is not significant in the 5-year model. In addition, the percent of GDP from agriculture is not significant in the 18-month model. In the 5-year model, the effect of the percent of GDP from agriculture is only significant at the 10% level. Furthermore, population density has a negative effect on conflict. This result reflects the fact that many developed countries,

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Table 6. Probit Model Results

Variable	Coefficient	Standard. Error	Marginal Effect	t-statistic	p-value
CONSTANT	**-0.9895**	**0.3944**	**-0.2419**	**-2.5089**	**0.0121**
POPG90_95	0.2124	0.2380	0.0796	0.8922	0.3723
POPG00_05	-0.1691	0.3290	-0.0654	-0.5139	0.6074
POPDENS	-0.0003	0.0002	-0.0001	-1.3534	0.1759
POPARAB	-0.0114	0.0171	-0.0045	-0.6649	0.5061
ENGIMP	-0.0009	0.0007	-0.0004	-1.2616	0.2071
FOODAID	0.0050	0.0046	0.0020	1.086	0.2775
AGGDP	**0.0490**	**0.0191**	**0.0144**	**2.5654**	**0.0103**
DEFOREST	**-0.3852**	**0.1579**	**-0.1499**	**-2.4391**	**0.0147**
H2OUSE	0.0015	0.0019	0.0006	0.7710	0.4407
FLOW	0.0006	0.0007	0.0002	0.8224	0.4108
Log Likelihood = -44.11 λ=42.96, p <<0.005					

Table 7. Logit Model Results

Variable	Coefficient	Standard. Error	Marginal Effect	t-statistic	p-value
CONSTANT	**-1.6153**	**0.6629**	**-0.4038**	**-2.4370**	**0.0148**
POPG90_95	0.3940	0.4778	0.0985	0.8245	0.4097
POPG00_05	-0.3226	0.6075	-0.0807	-0.5309	0.5955
POPDENS	-0.0005	0.0004	-0.0001	-1.3872	0.1654
POPARAB	-0.0196	0.0281	-0.0049	-0.6961	0.4864
ENGIMP	-0.0014	0.0012	-0.0004	-1.1672	0.2431
FOODAID	0.0082	0.0077	0.0021	1.0766	0.2816
AGGDP	**0.0841**	**0.0337**	**0.0210**	**2.4961**	**0.0126**
DEFOREST	**-0.6338**	**0.2626**	**-0.1585**	**-2.4133**	**0.0158**
H2OUSE	0.0023	0.0031	0.0006	0.7569	0.4491
FLOW	0.0009	0.0011	0.0002	0.8004	0.4235
Log Likelihood = -44.24 λ = 42.70, p << 0.005					

Table 8. Ordered Probit Results – 18-Month Conflict Risk

Variable	Coefficient	Standard Error	t-statistic	p-value
CONSTANT1	**1.1235**	**0.1965**	**5.7161**	**0.0000**
CONSTANT2	**2.3822**	**0.3167**	**7.5230**	**0.0000**
POPG90_95	0.1262	0.2093	0.6032	0.5464
POPG00_05	-0.0083	0.2816	-0.0297	0.9763
POPDENS	**-0.0004**	**0.0002**	**-2.5031**	**0.0123**
POPARAB	-0.0028	0.0132	-0.2156	0.8293
ENGIMP	-0.00002	0.0005	-0.0385	0.9693
FOODAID	0.0048	0.0036	1.3230	0.1858
AGGDP	0.0203	0.0130	1.5596	0.1188
DEFOREST	**-0.3317**	**0.1456**	**-2.2781**	**0.0227**
H2OUSE	-0.0001	0.0015	-0.0974	0.9224
FLOW	-0.000008	0.0006	-0.1394	0.8891
Log Likelihood = -95.58 λ = 30.72, p << 0.005				

Table 9. Ordered Probit Results – 5-Year Conflict Risk

Variable	Coefficient	Standard Error	t-statistic	p-value
CONSTANT1	**1.5368**	**0.2482**	**6.1917**	**0.0000**
CONSTANT2	**2.3035**	**0.3420**	**6.7348**	**0.0000**
POPG90_95	-0.1074	0.1985	-0.5411	0.5884
POPG00_05	0.2666	0.2771	0.9623	0.3359
POPDENS	**-0.0002**	**0.0001**	**-2.2140**	**0.0268**
POPARAB	-0.0030	0.0132	-0.2271	0.8203
ENGIMP	-0.00007	0.0003	-0.2180	0.8274
FOODAID	0.0014	0.0031	0.4560	0.6484
AGGDP	**0.0244**	**0.0139**	**1.7582**	**0.0787**
DEFOREST	-0.0545	0.1565	-0.3478	0.7280
H2OUSE	0.0004	0.0019	0.2018	0.8401
FLOW	0.0008	0.0007	1.0484	0.2944
Log Likelihood = -94.85 λ = 41.10, p << 0.005				

such as those in Western Europe, tend to be highly urbanized. These countries are also relatively peaceful. The likelihood ratio statistics for the 18-month and 5-year models are 30.72 and 41.10, respectively. These statistics are sufficient to reject the hypothesis that the model has no explanatory power at any standard level of significance.

These models mirror other models that have examined the correlation between socioeconomic variables and conflict in that there is no clear correlation between the two, and the correlation is often the opposite of what intuition would imply.[7] In addition, they find generally weak relationships between environmental variables and conflict. These results probably occur because environmental conditions may tend to exacerbate or accelerate existing conflicts, rather than generate conflict directly.[8]

These models can be use to generate forecasted probabilities of conflict for countries both in and outside the sample. Forecasts are computed for 117 countries. For the logit and probit models, the forecasted probability of conflict is computed. For the ordered probit models, the 18-month and 5-year probability that a country falls within a given conflict class (LOW, MODERATE, HIGH, or VERY HIGH) is computed for each country, conflict class, and time period. The result is 10 forecasted probabilities for each country. A complete listing of all of the probabilities is in the Appendix. Table 10 reports the 10 countries which have the highest probability of conflict from the logit and probit models, as well as the highest probability of falling in conflict class VERY HIGH in 18 months and 5 years for the ordered probit models. It is important to note that many of the countries that appear in the last two columns have relative low probabilities of VERY HIGH conflict. In fact, many of these countries have a higher probability of HIGH or

Table 10. Ten Countries with Highest Risk of Conflict

(Probabilities in Parentheses)

Probability of Conflict (Probit)	Probability of Conflict (Logit)	Probability of Conflict Class 3 (VERY HIGH) 18-Month	Probability of Conflict Class 3 (VERY HIGH) 5-Year
1. Angola (1.0000)	1. Angola (0.9997)	1. Ethiopia (0.7967)	1. Ethiopia (0.5094)
2. Ethiopia (0.9999)	2. Ethiopia (0.9985)	2. Angola (0.3904)	2. Somalia (0.4666)
3. Bangladesh (0.9958)	3. Myanmar (0.9874)	3. Sudan (0.3085)	3. Brazil (0.3114)
4. Myanmar (0.9941)	4. Bangladesh (0.9838)	4. Ghana (0.2821)	4. Myanmar (0.3019)
5. India (0.9871)	5. Uganda (0.9782)	5. Pakistan (0.2624)	5. Cambodia (0.2801)
6. Uganda (0.9858)	6. India (0.9776)	6. Uganda (0.2306)	6. Laos (0.2628)
7. Ghana (0.9835)	7. Ghana (0.9753)	7. Myanmar (0.2237)	7. Ghana (0.2426)
8. Cambodia (0.9826)	8. Cambodia (0.9751)	8. Nicaragua (0.2183)	8. Central African Republic (0.2419)
9. Laos (0.9747)	9. Laos (0.9684)	9. Paraguay (0.2114)	9. Angola (0.2411)
10. Somalia (0.9737)	10. Somalia (0.9663)	10. Laos (0.2095)	10. Uganda (0.2255)

MODERATE conflict. These results reflect the fact that environmental variables are more likely to generate conflict at the sub-national rather than international level.[9] However, some countries consistently appear in the top ten. The military may want to keep a close eye on these countries in the future.

VI.   CONCLUSIONS AND POLICY RECOMMENDATIONS

These results are a first attempt at using limited-dependent variable models to forecast potential environmental security threats in the future. They indicate that some environmental variables may be useful in predicting conflict. However, a complete model of conflict should include causes from non-environmental sources as well. The forecasts generated from these models seem to reflect current security conditions in various parts of the world.

It is unclear what direct role the United States military may play in mitigating the environmental conditions that may exacerbate conflicts. The U.S. military currently plays a role as the "world's policeman" in various part of the world. It is doubtful that it would be useful for it to become the world's garbage man as well. However, there are a few potential roles that the military may play. The first is as researcher. The military collects large amounts of satellite imagery that may be useful in generating more data on the decline of forests, the rate and degree of desertification, and the state of the polar ice caps. Since some of this data is classified, perhaps it is necessary to examine whether it would be useful to declassify some of this data and make it useful to researchers[10]. Second, the military may be able to act as a consultant to some developing countries on such things as water projects through the Army Corps of Engineers. By ensuring that these countries develop sensible resource use plans, the military may avoid involvement in conflicts in the

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future. Finally, the military can certainly use this information to ensure that its troops are properly trained for possible interventions in these areas in the future.

Environmental security is a relatively new field of research. These results indicate that environmental variables can predict conflict, although their ability to do so is weak at best. As more data becomes available, a clearer picture of the role that the environment plays in conflicts will emerge.

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[1] Thomas Homer-Dixon's (1994) research has uncovered evidence that environmental scarcities are already contributing to violent conflicts in many parts of the developing world.

[2] Homer-Dixon (1996) describes the statistical techniques that international relations researchers are currently using to analyze environmental conflicts. Although he does not specifically note the use of Pearson's Chi-Squared statistics, the table in Figure 3 (page 143) is the standard set-up to conduct a Pearson's Chi-Squared test.

[3] In the case of Rwanda in particular, Percival and Homer-Dixon (1996) note that environmental conditions were not the direct cause of the recent conflict there. However, they did aggravate the situation. Given the severity of environmental problems, such as rapid population growth and high population density in Rwanda, they find it surprising that they did not play a stronger role in the conflict.

[4] For further detail on the specification of the logit and probit likelihood functions and maximum likelihood estimation, see Maddala (1983), Chapter 2 or Greene (1993), Chapter 21.

[5] Source: http://www.countrydata.com/polriskrating.html

[6] Thomas Homer-Dixon, "Environmental Scarcities and Violent Conflict: Evidence from Cases," *International Security* 19 (Summer 1994): 6.

[7] Homer-Dixon (1994, p. 26) discusses this issue.

[8] See, for example, Percival and Homer-Dixon's discussion of the role of environmental variables in conflict in Rwanda (1996).

[9] Homer-Dixon (1994), p. 6.

[10] *Top Guns and Toxic Whales* (1991) refers to this data.

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APPENDIX

	Pr(Conflict) Probit	Pr(Conflict) Logit	Pr(LOW) 18-Month	Pr(MODERATE) 18-Month	Pr(HIGH) 18-Month
AFRICA					
Algeria	0.7186	0.7295	0.1678	0.3960	0.3583
Angola	1.0000	0.9997	0.0177	0.1457	0.4462
Botswana	0.5305	0.5343	0.2577	0.4242	0.2765
Cameroon	0.8933	0.8908	0.1602	0.3914	0.3659
Congo	0.9061	0.8914	0.2709	0.4253	0.2656
Cote d'Ivoire	0.8882	0.8960	0.0874	0.3203	0.4397
Egypt	0.8684	0.8695	0.0971	0.3335	0.4302
Gabon	0.9229	0.9034	0.2415	0.4220	0.2901
Ghana	0.9835	0.9753	0.0355	0.2121	0.4703
Guinea	0.7030	0.7255	0.1356	0.3736	0.3909
Kenya	0.8625	0.8723	0.0798	0.3089	0.4468
Libya	0.6937	0.6926	0.6893	0.2578	0.0509
Morocco	0.4544	0.4699	0.3183	0.4242	0.2294
Nigeria	0.8890	0.8881	0.2311	0.4200	0.2991
South Africa	0.3209	0.3216	0.3488	0.4200	0.2081
Sudan	0.9621	0.9551	0.0299	0.1941	0.4675
Tunisia	0.3780	0.3906	0.4682	0.3835	0.1376
Zaire	0.7280	0.7487	0.1447	0.3808	0.3815
Zambia	0.9035	0.9089	0.0836	0.3147	0.4433
Zimbabwe	0.5313	0.5528	0.2467	0.4228	0.2857
EUROPE					
Austria	0.1070	0.1160	0.6663	0.2735	0.0577
Belgium	0.0321	0.0419	0.9277	0.0674	0.0048
Bulgaria	0.2819	0.2851	0.5662	0.3353	0.0931
Czech	0.1374	0.1402	0.6868	0.2595	0.0516
Denmark	0.1159	0.1221	0.6944	0.2542	0.0494
Finland	0.2124	0.2185	0.4685	0.3834	0.1375
France	0.1307	0.1359	0.6486	0.2853	0.0633
Germany	0.0541	0.0644	0.8643	0.1226	0.0129
Greece	0.3780	0.3917	0.4808	0.3781	0.1313
Hungary	0.1082	0.1147	0.7269	0.2310	0.0407
Ireland	0.0983	0.1090	0.6742	0.2682	0.0553
Italy	0.0691	0.0781	0.8169	0.1618	0.0208
Netherlands	0.0191	0.0286	0.9753	0.0237	0.0010
Norway	0.3342	0.3255	0.5163	0.3616	0.1145
Poland	0.1402	0.1422	0.6740	0.2683	0.0554
Portugal	0.1020	0.1100	0.7008	0.2498	0.0476
Romania	0.4251	0.4348	0.5258	0.3568	0.1102
Russia	0.4352	0.4430	0.3682	0.4161	0.1953
Spain	0.1695	0.1739	0.5909	0.3211	0.0835
Sweden	0.1445	0.1519	0.5415	0.3487	0.1033
Switzerland	0.1019	0.1105	0.7638	0.2034	0.0318
Ukraine	0.7285	0.7522	0.3482	0.4201	0.2085
United Kingdom	0.0251	0.0361	0.9141	0.0795	0.0063
NORTH AND CENTRAL AMERICA					
Canada	0.2485	0.2524	0.4258	0.3997	0.1605
Costa Rica	0.7282	0.7453	0.1367	0.3746	0.3897
Cuba	0.3850	0.3940	0.4440	0.3931	0.1504

	Pr(Conflict) Probit	Pr(Conflict) Logit	Pr(LOW) 18-Month	Pr(MODERATE) 18-Month	Pr(HIGH) 18-Month
Dominican Rep.	0.6320	0.6438	0.2637	0.4248	0.2715
El Salvador	0.3144	0.3020	0.5355	0.3519	0.1059
Guatemala	0.7981	0.8105	0.1266	0.3658	0.4000
Haiti	0.9308	0.9236	0.1325	0.3710	0.3940
Honduras	0.8114	0.8245	0.0929	0.3280	0.4344
Jamaica	0.7454	0.7385	0.1595	0.3910	0.3665
Mexico	0.5005	0.5113	0.2764	0.4255	0.2613
Nicaragua	0.9263	0.9266	0.0543	0.2610	0.4664
Panama	0.5579	0.5756	0.2002	0.4110	0.3272
Trinidad & Tobago	0.2162	0.2032	0.6396	0.2911	0.0662
SOUTH AMERICA					
Argentina	0.3956	0.4003	0.3546	0.4189	0.2042
Bolivia	0.8610	0.8632	0.0999	0.3371	0.4273
Brazil	0.7806	0.7902	0.3467	0.4204	0.2095
Chile	0.5442	0.5651	0.3487	0.4200	0.2082
Colombia	0.6746	0.6910	0.2971	0.4255	0.2452
Ecuador	0.8068	0.8123	0.1802	0.4025	0.3462
Guyana	0.8345	0.8471	0.1794	0.4021	0.3469
Paraguay	0.9454	0.9397	0.0570	0.2668	0.4648
Peru	0.7660	0.7751	0.1443	0.3805	0.3819
Suriname	0.8487	0.8568	0.1366	0.3745	0.3898
Uruguay	0.2582	0.2645	0.4500	0.3908	0.1472
Venezuela	0.5991	0.6069	0.2718	0.4253	0.2650
ASIA					
Bangladesh	0.9958	0.9838	0.2723	0.4253	0.2645
China	0.4829	0.4908	0.3894	0.4109	0.1819
India	0.9871	0.9776	0.1583	0.3902	0.3678
Indonesia	0.7617	0.7779	0.2902	0.4257	0.2504
Iran	0.8006	0.8101	0.1566	0.3892	0.3694
Iraq	0.5118	0.5240	0.3162	0.4244	0.2309
Israel	0.5510	0.5772	0.5335	0.3529	0.1068
Japan	0.0608	0.0671	0.8716	0.1164	0.0118
Korea, S	0.0315	0.0402	0.9616	0.0365	0.0019
Kuwait	0.0226	0.0221	0.8324	0.1492	0.0180
Malaysia	0.8062	0.8180	0.1558	0.3886	0.3703
Myanmar	0.9941	0.9874	0.0523	0.2565	0.4674
Oman	0.4714	0.4474	0.2645	0.4248	0.2708
Pakistan	0.9687	0.9567	0.0404	0.2263	0.4709
Phillippines	0.7315	0.7392	0.2504	0.4233	0.2825
Saudi Arabia	0.5684	0.5640	0.1777	0.4013	0.3486
Singapore	0.0000	0.0000	1.0000	0.0000	0.0000
Sri Lanka	0.5603	0.5641	0.4544	0.3891	0.1448
Syria	0.3278	0.3443	0.5755	0.3300	0.0894
Thailand	0.6143	0.6216	0.2375	0.4213	0.2935
Turkey	0.4810	0.4962	0.3277	0.4232	0.2227
UAE	0.6181	0.6163	0.3215	0.4239	0.2271
Vietnam	0.6946	0.7050	0.3717	0.4153	0.1930
Yemen	0.8547	0.8669	0.1242	0.3635	0.4026

	Pr(Conflict) Probit	Pr(Conflict) Logit	Pr(LOW) 18-Month	Pr(MODERATE) 18-Month	Pr(HIGH) 18-Month
OCEANIA					
Australia	0.2534	0.2567	0.4135	0.4038	0.1675
New Zealand	0.3011	0.3089	0.3909	0.4105	0.1810
Papua New Guinea	0.4158	0.4308	0.2424	0.4221	0.2893
OUT-OT-SAMPLE-FORECASTS					
AFRICA					
Cent. Af. Rep.	0.9498	0.9485	0.0782	0.3063	0.4483
Eritrea	0.4455	0.4583	0.2416	0.4220	0.2900
Ethiopia	0.9999	0.9985	0.0007	0.0117	0.1849
Rwanda	0.8145	0.8197	0.3173	0.4243	0.2302
Somalia	0.9737	0.9663	0.0637	0.2805	0.4603
Uganda	0.9858	0.9782	0.0499	0.2509	0.4685
EUROPE					
Bosnia	0.0372	0.0427	0.7781	0.1925	0.0286
Croatia	0.1984	0.2031	0.6086	0.3105	0.0770
Macedonia	0.2285	0.2349	0.5604	0.3385	0.0954
Yugoslavia	0.7595	0.7713	0.1252	0.3645	0.4015
MIDDLE EAST					
Afghanistan	0.8363	0.8548	0.0592	0.2715	0.4634
Jordan	0.3906	0.4137	0.3045	0.4252	0.2395
Lebanon	0.2184	0.2218	0.6913	0.2564	0.0503
FORMER SOVIET CENTRAL ASIAN REPUBLICS					
Kazakhstan	0.6890	0.7125	0.2648	0.4249	0.2706
Kyrgyzstan	0.9294	0.9300	0.0984	0.3352	0.4289
Tajikistan	0.8916	0.8970	0.0855	0.3176	0.4415
Turkmenistan	0.8603	0.8687	0.1904	0.4072	0.3364
Uzbekistan	0.6053	0.6256	0.3216	0.4239	0.2270
ASIA					
Cambodia	0.9826	0.9751	0.0603	0.2738	0.4627
Korea, N	0.2424	0.2469	0.7039	0.2476	0.0468
Laos	0.9747	0.9684	0.0578	0.2684	0.4643
Nepal	0.8937	0.8974	0.1781	0.4015	0.3482

Pr(VERY HIGH) 18-Month		Pr(LOW) 5-Year	Pr(MODERATE) 5-Year	Pr(HIGH) 5-Year	Pr(VERY HIGH) 5-Year
	AFRICA				
0.0779	Algeria	0.2395	0.5569	0.1483	0.0553
0.3904	Angola	0.0547	0.4198	0.2844	0.2411
0.0417	Botswana	0.2773	0.5506	0.1287	0.0434
0.0825	Cameroon	0.1233	0.5240	0.2266	0.1262
0.0382	Congo	0.1157	0.5174	0.2327	0.1341
0.1526	Cote d'Ivoire	0.0913	0.4895	0.2534	0.1659
0.1392	Egypt	0.2197	0.5578	0.1596	0.0630
0.0464	Gabon	0.2389	0.5570	0.1486	0.0555
0.2821	Ghana	0.0542	0.4184	0.2848	0.2426
0.1000	Guinea	0.1569	0.5449	0.2007	0.0974
0.1645	Kenya	0.1233	0.5240	0.2265	0.1261
0.0020	Libya	0.1220	0.5230	0.2276	0.1275
0.0281	Morocco	0.3278	0.5345	0.1060	0.0316
0.0498	Nigeria	0.1471	0.5401	0.2080	0.1048
0.0231	South Africa	0.3414	0.5290	0.1006	0.0291
0.3085	Sudan	0.0635	0.4407	0.2773	0.2185
0.0107	Tunisia	0.3108	0.5408	0.1133	0.0352
0.0930	Zaire	0.1375	0.5344	0.2153	0.1127
0.1584	Zambia	0.1127	0.5145	0.2352	0.1376
0.0448	Zimbabwe	0.2803	0.5499	0.1273	0.0426
	EUROPE				
0.0025	Austria	0.5801	0.3788	0.0349	0.0061
0.0001	Belgium	0.7628	0.2250	0.0109	0.0013
0.0054	Bulgaria	0.4104	0.4946	0.0761	0.0189
0.0020	Czech	0.5442	0.4061	0.0418	0.0079
0.0019	Denmark	0.5889	0.3720	0.0333	0.0057
0.0106	Finland	0.4582	0.4657	0.0621	0.0140
0.0029	France	0.5612	0.3934	0.0384	0.0070
0.0002	Germany	0.7207	0.2623	0.0150	0.0019
0.0098	Greece	0.4176	0.4905	0.0739	0.0181
0.0014	Hungary	0.5329	0.4144	0.0442	0.0085
0.0023	Ireland	0.4701	0.4580	0.0590	0.0129
0.0005	Italy	0.6775	0.2996	0.0200	0.0029
0.0000	Netherlands	0.8271	0.1663	0.0060	0.0006
0.0077	Norway	0.4618	0.4634	0.0612	0.0136
0.0023	Poland	0.5306	0.4161	0.0446	0.0086
0.0018	Portugal	0.5417	0.4080	0.0423	0.0080
0.0072	Romania	0.3485	0.5259	0.0978	0.0278
0.0204	Russia	0.3434	0.5281	0.0998	0.0287
0.0045	Spain	0.5332	0.4142	0.0441	0.0085
0.0065	Sweden	0.4974	0.4396	0.0522	0.0108
0.0010	Switzerland	0.6063	0.3583	0.0304	0.0050
0.0232	Ukraine	0.2492	0.5559	0.1430	0.0519
0.0001	United Kingdom	0.7127	0.2694	0.0159	0.0020
	NORTH AND CENTRAL AMERICA				
0.0141	Canada	0.4127	0.4932	0.0754	0.0186
0.0990	Costa Rica	0.2890	0.5476	0.1231	0.0403
0.0125	Cuba	0.4091	0.4953	0.0765	0.0191

Pr(VERY HIGH) 18-Month		Pr(LOW) 5-Year	Pr(MODERATE) 5-Year	Pr(HIGH) 5-Year	Pr(VERY HIGH) 5-Year
0.0400	Dominican Rep.	0.3856	0.5080	0.0843	0.0221
0.0067	El Salvador	0.5091	0.4314	0.0494	0.0100
0.1075	Guatemala	0.1774	0.5522	0.1863	0.0841
0.1025	Haiti	0.1724	0.5507	0.1898	0.0871
0.1448	Honduras	0.1955	0.5559	0.1744	0.0741
0.0829	Jamaica	0.4478	0.4723	0.1650	0.0149
0.0368	Mexico	0.3679	0.5169	0.0905	0.0246
0.2183	Nicaragua	0.1283	0.5280	0.2225	0.1212
0.0616	Panama	0.3360	0.5312	0.1027	0.0300
0.0031	Trinidad & Tobago	0.6033	0.3607	0.0309	0.0052
	SOUTH AMERICA				
0.0223	Argentina	0.2922	0.5467	0.1216	0.0395
0.1356	Bolivia	0.0979	0.4982	0.2476	0.1562
0.0234	Brazil	0.0350	0.3567	0.2969	0.3114
0.0231	Chile	0.1827	0.5535	0.1828	0.0810
0.0322	Colombia	0.1731	0.5509	0.1893	0.0867
0.0711	Ecuador	0.1651	0.5482	0.1949	0.0918
0.0715	Guyana	0.0776	0.4683	0.2652	0.1889
0.2114	Paraguay	0.1103	0.5121	0.2372	0.1404
0.0933	Peru	0.1322	0.5308	0.2194	0.1175
0.0991	Suriname	0.1097	0.5115	0.2377	0.1411
0.0210	Uruguay	0.3783	0.5118	0.0868	0.0231
0.0380	Venezuela	0.2328	0.5574	0.1520	0.0578
	ASIA				
0.0378	Bangladesh	0.2567	0.5548	0.1391	0.0495
0.0178	China	0.3592	0.5210	0.0937	0.0260
0.0837	India	0.0778	0.4688	0.2650	0.1884
0.0337	Indonesia	0.2197	0.5578	0.1596	0.0630
0.0847	Iran	0.1684	0.5494	0.1926	0.0897
0.0285	Iraq	0.1784	0.5524	0.1857	0.0835
0.0068	Israel	0.5628	0.3922	0.0381	0.0069
0.0002	Japan	0.7614	0.2263	0.0110	0.0013
0.0000	Korea, S	0.7696	0.2190	0.0103	0.0012
0.0004	Kuwait	0.1032	0.5045	0.2431	0.1491
0.0853	Malaysia	0.2391	0.5570	0.1485	0.0554
0.2237	Myanmar	0.0372	0.3650	0.2959	0.3019
0.0398	Oman	0.2980	0.5450	0.1190	0.0381
0.2624	Pakistan	0.1295	0.5289	0.2215	0.1200
0.0437	Phillippines	0.3435	0.5281	0.0998	0.0287
0.0724	Saudi Arabia	0.1895	0.5549	0.1783	0.0772
0.0000	Singapore	1.0000	0.0000	0.0000	0.0000
0.0117	Sri Lanka	0.4087	0.4955	0.0767	0.0191
0.0050	Syria	0.1752	0.5516	0.1878	0.0854
0.0477	Thailand	0.3853	0.5082	0.0844	0.0221
0.0264	Turkey	0.3424	0.5286	0.1002	0.0289
0.0275	UAE	0.3579	0.5217	0.0942	0.0262
0.0199	Vietnam	0.2741	0.5514	0.1303	0.0443
0.1098	Yemen	0.1749	0.5515	0.1880	0.0855

Pr(VERY HIGH) 18-Month		Pr(LOW) 5-Year	Pr(MODERATE) 5-Year	Pr(HIGH) 5-Year	Pr(VERY HIGH) 5-Year
	OCEANIA				
0.0152	Australia	0.4140	0.4925	0.0750	0.0185
0.0176	New Zealand	0.4090	0.4954	0.0766	0.0191
0.0461	Papua New Guinea	0.2220	0.5578	0.1582	0.0620
	OUT-OT-SAMPLE-FORECASTS				
	AFRICA				
0.1673	Cent. Af. Rep.	0.0544	0.4191	0.2846	0.2419
0.0464	Eritrea	0.2516	0.5555	0.1418	0.0511
0.7967	Ethiopia	0.0100	0.2047	0.2759	0.5094
0.0283	Rwanda	0.1699	0.5499	0.1916	0.0887
0.1955	Somalia	0.0132	0.2342	0.2861	0.4666
0.2306	Uganda	0.0606	0.4342	0.2797	0.2255
	EUROPE				
0.0001	Bosnia	0.2602	0.5542	0.1373	0.0484
0.0039	Croatia	0.4714	0.4571	0.0586	0.0128
0.0056	Macedonia	0.4426	0.4755	0.0665	0.0154
0.1088	Yugoslavia	0.3327	0.5326	0.1040	0.0307
	MIDDLE EAST				
0.2059	Afghanistan	0.3162	0.5389	0.1109	0.0340
0.0307	Jordan	0.3648	0.5184	0.0917	0.0251
0.0020	Lebanon	0.6642	0.3109	0.0218	0.0032
	FORMER SOVIET CENTRAL ASIAN REPUBLICS				
0.0398	Kazakhstan	0.1803	0.5529	0.1844	0.0824
0.1375	Kyrgyzstan	0.0956	0.4953	0.2496	0.1595
0.1554	Tajikistan	0.1051	0.5066	0.2416	0.1468
0.0661	Turkmenistan	0.1344	0.5324	0.2177	0.1155
0.0275	Uzbekistan	0.2031	0.5569	0.1696	0.0704
	ASIA				
0.2032	Cambodia	0.0426	0.3843	0.2929	0.2801
0.0018	Korea, N	0.4185	0.4899	0.0736	0.0180
0.2095	Laos	0.0476	0.4000	0.2897	0.2628
0.0722	Nepal	0.1199	0.5212	0.2292	0.1296